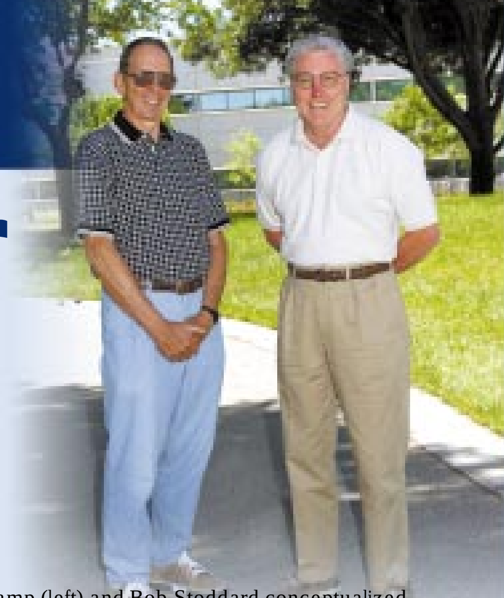
The Optical Modulator and Switch: Light on the Move



Ted Wieskamp (left) and Bob Stoddard conceptualized the Optical Modulator–Switch and collaborated with teams from AlliedSignal and the University of Maryland at College Park to develop the device.

WHETHER it's the Internet or telephone lines, most communication systems these days rely at least partly on fiber optics to carry information in the form of light signals. The most daunting fiber-optic problems facing the communications industry are the high costs of modulating data signals onto a laser beam and switching signals from one channel to another. The recently developed Optical Modulator–Switch (OMS) provides a simple, inexpensive solution to both problems in a single, small package.

The OMS was initially conceived by Bob Stoddard and Ted Wieskamp of Lawrence Livermore's Engineering Directorate as a possible optical strong link that could be used in weapon systems. AlliedSignal Federal Manufacturing & Technology in Kansas City designed the switch, while the University of Maryland at College Park provided integrated circuit design and development for the R&D 100 Award–winning system.

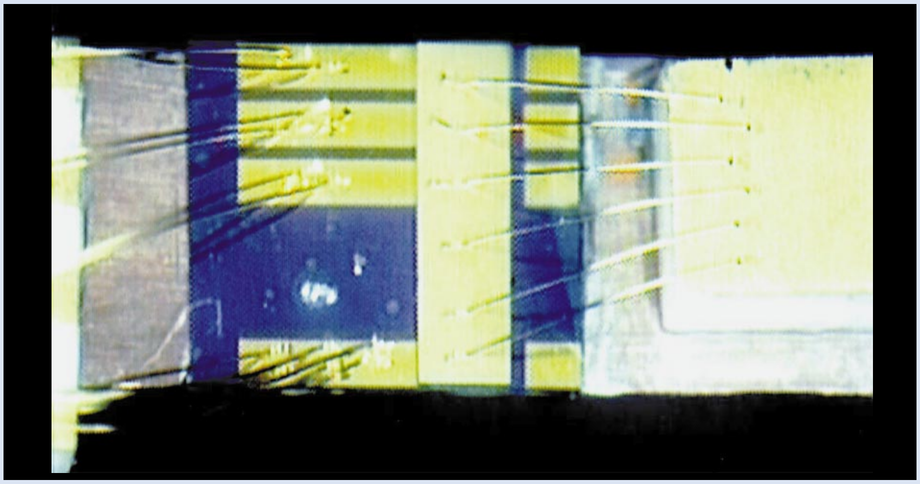
"At the Lab, we wanted a switch that could be coded," Wieskamp explains. "We got that and also signal amplification in the bargain. The final design of this device provided a significant amount of gain when the switch was on. This made it really useful for communications applications."

The principal application of the OMS is as a modulator or switch in optical communication systems. However, Wieskamp points out, it could also be used as a control device for laser systems, as a security device for data communication systems, as a lock to protect valuable property, and as a switchable amplifier for small laser signals.

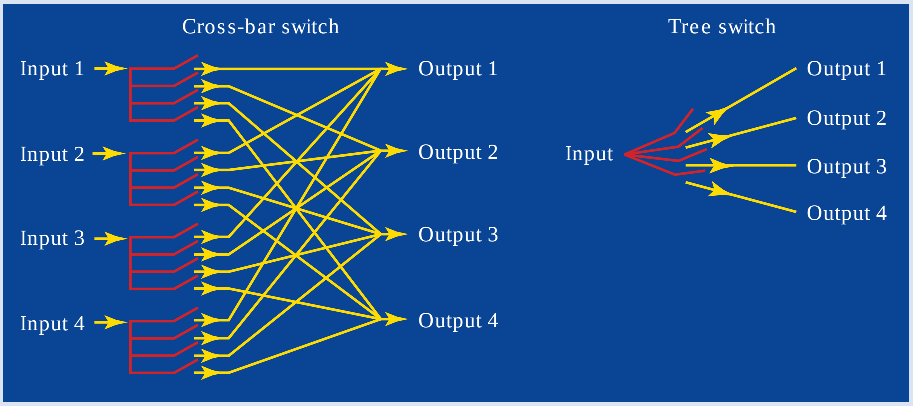
OMS as a Modulator

In fiber-optic communications, information can be carried by a light wave of varying amplitude (changing brightness). The amplitude is varied by modulating the single-wavelength light coming from a laser source. The OMS varies the brightness of a low-level laser light source by switching it on and off at nanosecond rates. Then its built-in amplifier boosts the varying signal to levels suitable for transmission over long optical communication links.

As Wieskamp explains it, commercially available modulators do not amplify the signal. This means that a separate amplifier—



The optical modulator–switch. Fiber-optic input lines come in from the left and attach to the switches on the series of horizontal bars. The built-in amplifier lies under the vertical bar in the center; output lines exit to the right. The entire device fits on the end of a pencil eraser.



In a cross-bar switch (left), any of the inputs may be amplified and connected to any of the outputs. This type of switching is commonly used in optical communication. In a tree connection (right), a single input may be connected to any combination of outputs. The more outputs used, the more important it is to amplify the signal. Here, each output will have about one-quarter of the original input power. If ten outputs are needed—a common configuration for the communications industry—each output signal will approach one-tenth of the original.

which can cost thousands of dollars—must be added to the communication chain after the modulating device.

The OMS device, contained on a chip as big as a medium-size integrated circuit, derives its built-in amplification from the interaction of input signals with semiconductor material. Inside the device, photons from the input signal travel through a waveguide with an applied electric field. This electric field has been exciting atoms in the device's semiconductor material and increasing their energy. When the photons pass through the semiconductor, they cause the semiconductor atoms to give up energy and become photons just like them—of exactly the same wavelength, traveling in the same direction. This increase in the number of photons thus amplifies the signal.

OMS as a Switch

When used as a switch, the OMS can receive signals in different configurations and switch them out in any combination of outputs. The figure above shows its use in both cross-bar and tree switching of optical signals. In switching the optical signals—again, an on-and-off action—the OMS is a thousand times faster than current optical switches.

With many signal outputs, amplification becomes particularly critical. An optical signal can lose half of its input power every time it is sent through a switch or any type of connector; it loses an equal amount traveling through 4 kilometers of fiber. For a signal going across the country, from, say, San Francisco to Washington, DC, this adds up to significant power losses. To counteract these losses, such signals must be amplified or boosted as they are switched and relayed over complex routes or long distances.

Cheaper, Smaller, Simpler, Faster

The OMS has no direct competitors, because no other device has its combined modulation and switching capabilities. Even with its superior capabilities, the OMS still wins hands down in terms of cost, size, simplicity, and speed when compared with commercially available systems. For instance, mechanical and heat-operated switches cost in the neighborhood of $500, while nonlinear optical switches cost about $5,500. The OMS costs less than $50.

As for size, mechanically operated or nonlinear optical switches are about the length of this line of text and are about as wide as a four- or five-line paragraph on this page. Other switches, including heat-operated switches, are far larger. The OMS is 1 by 4 millimeters, barely large enough to cover the end of a pencil eraser.

Commercially available switches tend to have complex designs that depend on expensive technologies. Heat-operated switches depend on expensive polymer waveguide technology. Mechanically operated switches use devices such as moving fiber collimators, which are both expensive and slow. The nonlinear optical switch requires careful alignment of precision-machined crystals, a time-consuming and expensive process. In addition, the nonlinear switch requires external electronics and is highly sensitive to changes in temperatures. The OMS uses conventional integrated circuit technology, making it simple and inexpensive to manufacture. Its built-in amplification further reduces complexity and increases reliability.

The OMS also saves space. "Space is expensive," says Wieskamp. "If you can shrink switching and routing components so equipment fits into a one-story building instead of a four-story building, then you save a lot of money.

"The OMS is a true state-of-the-art development in modem optics," concludes Wieskamp. "No other device is currently available that both modulates and amplifies an optical communications signal. It's a real breakthrough in modulation and switching."

—Ann Parker

Key Words: amplitude modulation, fiber-optic communications, Optical Modulator–Switch (OMS), signal amplification.

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